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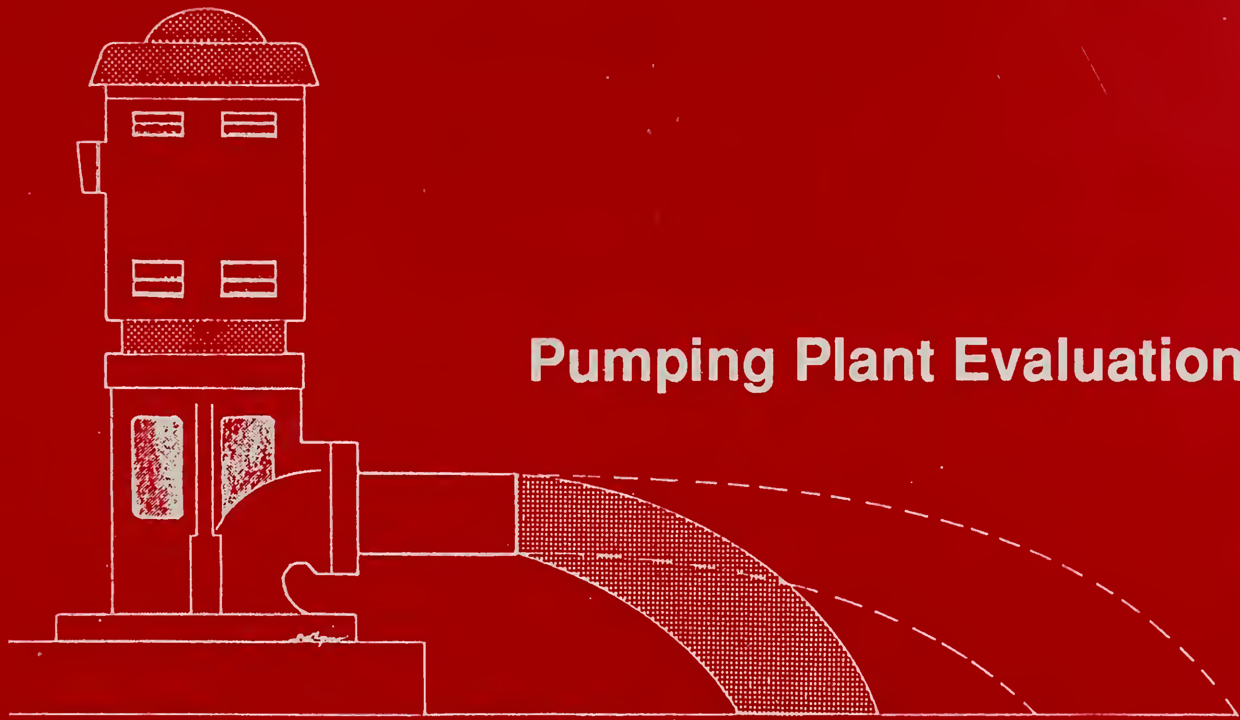
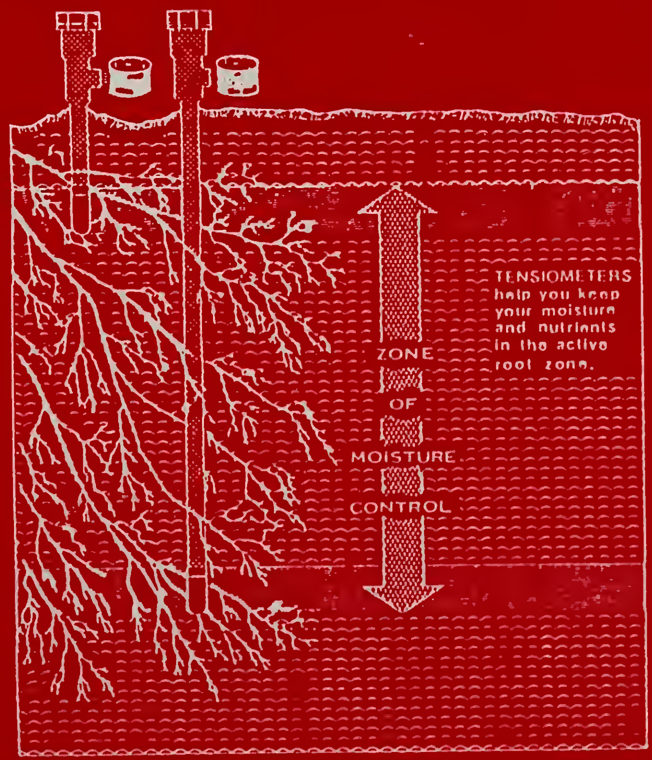
New Mexico

Irrigation Water Management Study



Pumping Plant Evaluations



Irrigation Scheduling

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IRRIGATION WATER MANAGEMENT STUDY

Hidalgo and Luna Counties, New Mexico
April 1991

Sponsored By:
DEMING SOIL AND WATER CONSERVATION DISTRICT
HIDALGO SOIL AND WATER CONSERVATION DISTRICT
NEW MEXICO STATE ENGINEER OFFICE

With Assistance From:
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Albuquerque, New Mexico

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INTRODUCTION

This report demonstrates how to boost profits by cutting costs and increase income by investing your time and money in wiser application of irrigation water. Improving irrigation efficiency is not a simple matter, because applying water to crops is both a science and an art.

This report contains practical information on irrigation techniques developed from onsite experiences and case studies of the Hidalgo y Luna River Basin Study. It will help you assess your present irrigation system, identify areas of potential improvement in applying water, and demonstrate practical methods of achieving better water use. It will help you increase your net income.

YOUR BIGGEST PRODUCTION COST ITEM--IRRIGATION

Irrigation can comprise up to half of a crop's total production expense. It is a logical place to look closely for ways to control input costs. Any inefficiency or waste in applying water means higher energy bills, increased pump maintenance costs, increased irrigator wages, and high personal labor requirements. Through improved water use, you can eliminate the unneeded portions of these expenses.

Efficient irrigation improves income by increasing yields. Precise watering supports better crop yields. Both over-irrigation and under-irrigation reduce production. Proper amounts, timing, and distribution of irrigation water affect plant growth through improved nutrient use and soil conditions. Proper irrigation efficiency also affects one of our most precious resources, water. Poor irrigation efficiencies have an adverse affect on water quality and availability. Excess application of water reduces the amount available for irrigation and may cause deep percolation or tailwater runoff. These losses degrade water quality.

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STUDY OBJECTIVES

This report was completed as part of the Hidalgo y Luna Cooperative Basin Study. The study was done under the authority of Section 6 of Public Law 83-566, as amended.

The sponsors' four objectives for this study are as follows:

1) Determine physical and economic effects of conservation practices, systems of practices, and management techniques.
2) Assess erosion on abandoned or idled cropland and present methods, costs, and benefits in establishing perennial vegetation.
3) Provide assistance to farmers with identified alternative crops by developing consumptive water use requirements and recommending conservation practices and systems of practices needed by each crop.
4) Identify and evaluate opportunities for project assistance through other USDA programs.

HOW TO USE THIS REPORT

This report has six sections. The first section is *Operating Your System at Its Potential.* This portion of the report explains the fundamentals of irrigation. It describes how an irrigator can improve water management, reduce cost of production and improve yields.

The second section--*Study Findings*--presents specific recommendations that all irrigators should incorporate into their operation. This section also presents area wide recommendations. Politicians, bankers and regional planners will benefit from this information.

The third section--*Changing or Improving Your System*--compares irrigation systems. An irrigator can use this section to compare his system with other systems. This section will assist the irrigator in determining other systems to investigate before deciding on a change.

The fourth section--*Alternative Crops*--addresses study objective 3. The irrigator will find information on chile, onions, Afgan pines, pecans, spinach, grapes and pinto beans.

The fifth section--*Erosion on Idled Cropland*--addresses study objective 2. It discusses the difficulties of converting abandoned cropland to rangeland and the potential for alternative crops.

The sixth section--*Description of the Study Area*--provides a brief overview of the climate, geology, soils and water resources.

OPERATING YOUR SYSTEM AT ITS POTENTIAL

WHY EVALUATE YOUR SYSTEM'S EFFICIENCY?

The number of acres irrigated and the irrigation cost per acre depend on the efficiency of the irrigation system. The higher the efficiency is, the lower the cost of irrigation will be. The higher the efficiency is, the higher the crop production will be.

Take a typical 450 gallon per minute (GPM) well and look at some system efficiencies. Historically, a rule of thumb has been that 10 to 12 GPM is needed per acre. Thus, a 450 GPM well would adequately irrigate 37.5 to 45 acres. However, if you could reduce this requirement to 7 GPM per acre, savings in water and irrigation cost would be 30 to 40 percent.

A typical irrigation cost is $125 per acre. A 30 to 40 percent savings translates to a $37.50 to $50 per acre savings, or $3,750 to $5,000 for 100 acres. This change would mean that you could irrigate approximately 64 acres with the same amount of water.

The savings in irrigation cost could even be greater than 30 percent if you could irrigate at night and take advantage of a lower energy rate for off-peak usage.

IRRIGATION SYSTEM COMPONENTS

The three basic components of an irrigation system are the <u>pumping plant</u>, <u>conveyance system</u>, and <u>application of irrigation water</u>.

The efficiency of the pumping plant will affect every acre-inch of water pumped. If the efficiency of a 450 GPM pump was increased from 50 to 75 percent, the savings in cost of pumping could be 33 percent. For the same cost, the amount of water pumped would increase by 50 percent. When a pump is overhauled, there is usually a combination of increase in water and decrease in cost per acre-inch of water pumped. Three pumping plants were overhauled during this study. The costs and results of each are discussed on pages 10-12.

The conveyance system consists of either underground pipeline or open ditch, and it transports water from the well to the field. Underground plastic pipeline is efficient in conveying water because it does not lose water to evaporation and seepage. A concrete lined ditch is also efficient in conveying water, but it loses water through evaporation. Earthen ditches lose more water than any other conveyance system. They lose water through seepage and evaporation. In the study area, there are not many earthen ditches; but where they are used, water loss can be substantial. The seepage loss can be as high as 25 percent on sandy loam soils. Irrigation studies on fine sandy loam soils indicate that for each quarter mile of earthen ditch, evaporation and seepage can cause a water loss of 20 to 25 percent.

Storage reservoirs are another part of a conveyance system. Not many of these are used, however, they can have a substantial water loss. Proper lining of the bottom and sides of reservoirs will reduce water losses to seepage.

The third component of an irrigation system is the application of irrigation water on the field. This component has two parts: the irrigation hardware and irrigation water

management. Types of irrigation systems include surface systems, such as furrow or graded borders; sprinkler systems; and drip systems. The system is usually in place on a given field, and it is expensive to change from one irrigation system to another. Information on the cost and effects of changing systems is discussed on pages 22 through 27.

Irrigation water management (IWM) is the efficient application of the right amount of water at the right time. This process involves scheduling irrigations, determining how much water to apply, and checking overall application efficiency. Irrigation water management is probably the least understood aspect of irrigation, and you will have more difficulty controlling water loss in the field than in the ditch or at the pump. For instance, when you improve a pump's efficiency, the pump delivers more water. Also, you can visualize the amount of water lost from a dirt ditch. It is, however, difficult to visualize deep percolation losses.

MEASUREMENTS YOU NEED TO KNOW

In order to operate your system at its potential, you need to know:
- your pump capacity,
- the crop's rooting depth,
- the available water capacity of your soil,
- the moisture presently available in your soil, and
- your overall application efficiency.

These measurements are defined and discussed below. An example of how to use the measurements follows the definitions. You can make these measurements yourself, or get help from the local SCS office or from an irrigation consultant.

First, you need to know your pump capacity, which is the amount of water delivered by your pump in gallons per minute. Once you have measured the discharge rate, divide the rate by 450 to convert GPM to acre-inches per hour. For example, if your pump is producing 450 GPM, it is producing one acre-inch per hour, and 675 GPM equals 1.5 acre-inches per hour. It is important to determine acre-inches per hour, since the crop's water needs are expressed in inches of water per acre, or acre-inches. Next, multiply the acre-inches per hour by 24 to determine the amount of water produced by your well in one day. If your pump produces 1.5 acre-inches per hour, then it delivers 36 acre-inches per day (1.5 x 24 = 36).

The crop's rooting depth is the depth at which the soil is supplying moisture to the roots. This depth will change throughout the growing season.

Another important factor is the available water capacity of the soil, which is the amount of water which the soil holds for the plant. It is the amount of water the soil holds against the force of gravity minus the amount left in the soil when the plants begin to wilt and die. Irrigation water applied in excess of the available water capacity is wasted through percolation beyond the crop's rooting depth.

The best way to determine when to irrigate is to measure the amount of water presently available in the soil. By knowing how much water is available, the experienced irrigator can effectively determine when to apply the next irrigation. Producers use several methods to estimate soil moisture content and schedule irrigation applications. One popular method is by feel and appearance. It is done by digging a hole and sampling the soil at various depths throughout the root zone. Other irrigators use various soil moisture

monitoring devices, such as tensiometers and gypsum blocks. Once you know the amount of water present in the soil, subtract it from the available water capacity of the soil to find out how much water to apply during the next irrigation.

The overall application efficiency is the amount of water which you must pump in order to place an acre-inch of water in the root zone. It can determine how long to run your pump during an irrigation. Suppose your pump supplies 36 acre-inches per day, the soil needs two inches of moisture replenishment, and your overall application efficiency is 50 percent. How many acres should you irrigate in a day? The answer is nine acres (36 / 2 x 50% = 9). If your overall application efficiency is 75 percent, then you could irrigate 13.5 acres per day. You cannot irrigate 18 acres per day in this example because your conveyance and application systems have built-in inefficiencies.

The following is an example of how you would use the above measurements on a 24 acre field of chile. You know the following information based on measurements:

- your pump capacity is 675 GPM.
- the crop's rooting depth is 18 inches, or 1.5 feet.
- the soil water holding capacity of your soil is 2 inches per foot (soil type is Mimbres silty clay loam).
- the moisture presently available in your soil is at 50 percent or 1 inch per foot (your tensiometer readings helped you determine this).
- your overall application efficiency is 50 percent (this is based on an irrigation evaluation).

Therefore, your pump is delivering 1.5 acre-inches of water per hour (675 GPM / 450 = 1.5). The amount of water needed to refill the root zone is 1.5 inches (2 inches per foot - 1 inch per foot X 1.5 feet of root zone = 1.5). The total amount of water needed to fill the root zone is 36 acre-inches (1.5 inches X 24 acres = 36 acre-inches). The total amount of water you will pump for this irrigation is 72 acre-inches (36 / 50% = 72). Therefore, the chile can be irrigated in 48 hours (72 acre-inches / 1.5 acre-inches per hour X 24 hours = 48).

PLANNING CROP ACREAGES WITH CONSUMPTIVE USE

Use pump capacity and the irrigation needs of the crops to plan the combination of crops and acres to be planted. Because the planted acreage should not exceed the capacity of the pump, knowing your crop's consumptive use (CU) can help you plan an irrigation system. Base the CU on the maximum CU for the crop, otherwise there will not be enough water to go around.

It usually takes 10 to 12.5 GPM per acre to water a crop. Thus, a 450 GPM pump could, on the average, irrigate 36 to 45 acres (450 / 12.5 = 36 or 450 / 10 = 45).

A better estimate can be determined. For example, based on normal weather conditions, a chile crop should use about 0.23 inches of water per day in September. This is equal to 4.3 GPM (0.23 acre-inches per acre X 450 / 24 hours = 4.3). Assuming an irrigation efficiency of 50 percent, the pump must produce 8.6 GPM per acre (4.3 / 50% = 8.6). Therefore, a pump producing 450 GPM can irrigate a maximum of 52 acres (450 GPM / 8.6 GPM per acre = 52) of chile, and no other acreage, during September. Additional acreage of any crop will force the producer to stress the crop and may result in production losses.

You can optimize pumping capacity if the periods of maximum consumptive use are staggered throughout the growing season. Onions have maximum consumptive use in June and July. Summer lettuce has its maximum consumptive use in September and October. Winter lettuce's consumptive use peaks in May. Cotton has its maximum consumptive use in August. The maximum consumptive use of corn and sorghum varies with planting and maturity dates.

SCHEDULING AN IRRIGATION

One of the most significant accomplishments of this study has been better irrigation scheduling. Throughout the study, wise scheduling has resulted in less water being applied or in reduced crop stress. The reduced stress has resulted in better yields. The reduced water application has reduced pumping costs and conserved water.

Irrigation scheduling is extremely important in efficient operations. Scheduling consists of planning to apply irrigation water when the crop needs it.

If you wait too long to irrigate, the crop will use the available water in the root zone and enter a critical stress situation. Crop stress causes loss of production. When you wait to see plant stress before irrigating, production loss has probably already occurred.

Scheduling irrigations also prevents over-watering of the crop. Over-watering can cause production losses and can increase production costs.

How do you know when to irrigate? Scheduling devices used during this study include consumptive use rates, tensiometers, gypsum blocks, atmometers, soil probes, and an infrared gun. These devices can help you plan water use and increase profits.

IRRIGATION SCHEDULING TOOLS

A basic scheduling tool is a soil probe. Even if you rely on other scheduling devices, a soil probe is vital. The probe can verify readings from the other devices, determine the uniformity of soil moisture throughout the field, and check the amount of irrigation water applied.

Tensiometers were evaluated extensively during the study to determine their effectiveness in scheduling irrigations. A tensiometer measures the tension exerted on water in the soil. As soil dries, the tension, which the soil particles exert on the remaining moisture, increases. Without irrigation, this tension will increase until the plant cannot draw moisture into its roots. The tensiometer readings are calibrated to soil moisture content for each soil. As readings increase, you can predict when an irrigation will be needed.

Gypsum blocks were also used in the study. A gypsum block measures the electrical resistance of the soil. This resistance changes with soil moisture. Readings are taken with a resistance instrument which is similar to an ohm meter. These readings can help you predict when an irrigation will be needed.

The study team made limited use of an atmometer, which worked well for determining evapo-transpiration rates. An atmometer is mounted on a fence post or pole in the field. They are easy to read and calibrate, but cannot be used to determine the moisture in the soil. It does not register the effects of rainfall or of an irrigation.

The team made very limited use of an infrared gun. Due to its cost, it would be most useful on large operations. It measures the temperature of the plant. An increase in temperature is associated with plant stress. Disease, pests, or reduced evapo-transpiration can cause stress. As the root zone dries out, the plant cannot transpire as much moisture, and its temperature increases. The main advantage of the infrared gun is its portability. The gun, like the soil probe, can determine the uniformity of soil moisture throughout the field.

APPLYING A PRE-PLANT IRRIGATION

A pre-plant irrigation is different from a normal irrigation, because it usually takes more water to pre-irrigate a soil before planting. This irrigation will usually have the lowest irrigation efficiency of the season. The low efficiency is due to the dryness of the soil, the rough condition of the soil surface, and deep percolation losses. The depth of a pre-plant irrigation will depend on the rooting depth of the mature crop. The total amount of water to apply will depend on the available moisture and the water holding capacity of the soil.

APPLYING IRRIGATION WATER EFFICIENTLY

The least understood factor in irrigation is overall application efficiency. It is a subject of considerable controversy and research. Greatest water savings can result from higher application efficiencies and better scheduling. A major portion of this study was devoted to improving irrigation efficiency. Overall application efficiency has two parts: application efficiency and uniformity. Overall application efficiency equals the application efficiency times the uniformity. A post irrigation check determines your overall application efficiency.

Application efficiency is the amount of water needed to fill the root zone divided by the amount of water applied. For example, two inches of water are needed to replace soil moisture in the root zone of a chile crop, but four inches are applied. The application efficiency is 50 percent (2 / 4 X 100% = 50). As stated earlier, no one can apply water at 100 percent efficiency. However, the application efficiency affects irrigation costs as well as the amount of acreage that you can irrigate. (Refer to "Planning Crop Acreages with Consumptive Use," page 3).

The uniformity of application is as important as application efficiency. Uniformity refers to the evenness of water application along the length of furrow and across the entire field. Typically, a graded furrow has a drier zone about two-thirds of the way down the furrow (measured from the lateral). How uniformly you apply water will affect overall efficiency and production. To determine uniformity, you should probe every 100 feet along a furrow. Average all the probe depths, and average the shallowest 25 percent of probe depths. Divide the average of the shallowest 25 percent of probe depths by the average of all the probes.

You should use a post irrigation check 24 to 48 hours after irrigating. Use a soil probe at the upper, middle, and lower thirds of the field. The soil probe will indicate the depth of water application. The driest part of the field will normally be near the beginning of the lower third of the field. You can also use tensiometers or gypsum blocks to determine the amount and depth of water application.

The post irrigation check can evaluate your overall application efficiency. Divide the amount of water needed to fill the root zone by the amount of water applied. This figure represents the application efficiency. Divide the shallowest probe depth (or average of the shallowest 25 percent of probe depths) by the average of all the probe depths. This figure represents uniformity. Finally, multiply the application efficiency times the uniformity factor to determine your overall application efficiency.

CONSIDERATIONS FOR IMPROVING IRRIGATION EFFICIENCY

Soil moisture monitoring instruments are usually installed near the driest part of the field. You should check moisture and rooting depth at the upper and lower ends of the field and correlate moisture content at these points with the instrument readings. As a minimum, correlation should be done at the beginning of the irrigation season.

Scheduling instruments and soil probing are used to determine the amount and depth of water application. The rooting depth of the crop will determine the depth at which you should apply water. If the rooting depth is two feet, soil moisture replacement is needed to that depth. Irrigation water that moves below the root zone is called deep percolation water. It represents costs for pumping which are not benefiting the crop.

Soils have different water holding capacities which are primarily dependent on the texture (size of soil particles) of the soil. A silty clay loam soil will normally provide two inches of available water per foot of depth. If the water holding capacity is two inches per foot, and the soil moisture content is 50 percent, you should replace one inch of water per foot of rooting depth. This is the net amount of water to be replaced. If your efficiency is 75 percent, pump 1.3 inches of water per foot.

Soil intake rates vary considerably among different soils. A silty clay loam soil will take in water much more slowly than a sandy loam soil. Usually, a soil will take in water more quickly at the beginning of the season than at the end of the season. A soil's intake rate can vary from year to year. The rate will also vary according to the volume of water in the furrow and the moisture content of the soil. Rainfall and the surface condition in the furrow can also affect the intake rate.

Based on soil intake rate, you can vary the furrow flow rate to increase efficiency. Applying the proper amount of water uniformly is dependent on the amount of water (GPM) applied per furrow. The GPM per furrow is determined by the intake rate, amount of water needed, and furrow condition If you apply too many GPM to the furrow, the water may reach the lower end of the field too quickly. The field will be under-irrigated, or a large volume of tail-water will result. If you apply too little water, all of it will soak into the upper end of the field before reaching the lower end. A soil with a high intake rate will need a higher GPM than one with a slow intake rate. A soil with a high intake rate (loamy to sandy loam) will normally need 30 or more GPM per furrow. A soil with a slow intake rate (silty clay loam) will normally need 10 to 30 GPM per furrow. (These GPM figures are based on 1,320 feet length of run).

Furrow condition can affect GPM rates. A cultivated furrow with two inches of loose soil will slow water down considerably. A firmly "water packed" furrow will speed up water considerably. A soil with a slow intake rate in cultivated furrows could need 10 to 15 more GPM to account for the roughened soil surface. A soil with a high intake rate with firm water packed furrows will require about 30 GPM per furrow. Generally, the needed GPM per furrow will be higher at the beginning of the season because of cultivated conditions. You should reduce the GPM after cultivation is complete.

Too often, the value of rain is overrated. The crop may look good after last night's rain, but it may only provide moisture for a day or two. You should evaluate each rain as you would an irrigation application. Otherwise, stress may occur. Remember, "When it starts to rain, turn the pumps on," and check the moisture in the root zone.

STUDY FINDINGS

The study concentrated on ways to save irrigation water to conserve ground water and improve water quality. Study emphasis was placed on the pumping plant and the application of irrigation water. For pumping plants, the study found that efficiency and power supply were areas of concern. For the application component, the study found that proper scheduling and higher overall application efficiency could improve a farmer's operation. These four areas affect the cost of irrigation and have an impact on crop production.

Farmers in Hidalgo and Luna Counties are in the age of scientific farming. The use of science in farming includes production of a variety of crops and requires precise timing and application of nutrients and pesticides. Crops currently being grown in the study area include cucumbers, pumpkins, onions, lettuce, cotton, grain sorghum, corn, chile, alfalfa, barley, grapes, and spinach.

No gross mismanagement of irrigation water was found in the study area. In most cases, farmers were doing a satisfactory job of applying irrigation water. However, it was found that proper scheduling, irrigation water management, and improved application and uniformity efficiencies can reduce irrigation costs and increase yields.

Drip systems were not evaluated during the study. However, most published data shows that drip systems are very efficient. The initial cost of installation prohibits their use in most farming situations, except on high value speciality crops.

STUDY ORGANIZATION

The study was implemented by placing two SCS Soil Conservationists in the study area. One was located in Deming (Luna County) and the other was located in Lordsburg (Hidalgo County). They supplemented the existing staffs and spent all of their time working with farmers on data collection. They provided assistance in irrigation water management and in evaluation of the effects of conservation practices.

STUDY ACCOMPLISHMENTS

As a result of the study, 45 irrigators were aided in improving their irrigation systems or irrigation techniques. This assistance would not have occurred under existing conservation programs. Study personnel worked intensively with 30 farmers in Luna County and with 15 farmers in Hidalgo County. It was found that the most success was attained by working individually with a farmer. The two Soil Conservationists worked with each of these farmers over the three-year study period. This assistance resulted in a 10 to 20 percent increase in production and a 10 to 30 percent savings in water. Water savings and better yields increased the farmers' net income which will probably be spent in the local area.

Farmers' response to the study was positive. There are about 200 irrigators in Luna County and about 75 in Hidalgo County. The two Soil Conservationists worked intensively with only 16 percent of these irrigators. With the completion of the study, the conservationists were moved to other locations.

IMPLEMENTATION OF STUDY RESULTS

The findings of this study can be used by irrigators within and outside of the study area. The results are applicable to many cropland areas in New Mexico and may be appropriate for cropland in other areas of the Southwest.

Implementation of findings in the study area depends on follow-up assistance to irrigators. This assistance will disperse the study findings to more farmers and assist them in improving their use of irrigation water.

STUDY RECOMMENDATION

The recommendation is based on the response and interest of area farmers and the findings of this study. It is recommended that an Irrigation Water Management Assistance Program be developed. This program should focus on the individual farmer who does his own irrigating. It should emphasize irrigation scheduling and the new application techniques introduced during the study. The program should continue to assist area farmers in determining their application and uniformity efficiencies and in testing irrigation pumping plants.

Carrying out the recommended program would require adequate funding and support. Based on the number of acres in the study area and the number of acres serviced by the two Soil Conservationists during the study, it is recommended that two full-time irrigation specialists are needed in Luna County and one is needed in Hidalgo County.

This program would increase economic returns in a rural area. Benefits would include increased production and decreased pumping costs, water costs, and irrigation labor costs. Public funds could be used to support this staffing. Funding for these positions could come from a variety of sources, including the local Soil and Water Conservation Districts, Black Range Resource Conservation and Development Corporation, Soil Conservation Service, and County Government. This program could also be developed as a private enterprise. Farmers use consultants to locate, identify, and spot treat pest and nutrient problems. Irrigation professionals or consultants could assist farmers in identifying ways to control the cost of irrigating and to reduce crop stress.

During the study, improvements in the use of water evolved and are continuing to spread throughout the area. These changes grew out of the one-on-one contact between the Soil Conservationists and the irrigators. If continued support and assistance is available, these positive effects will spread rapidly. If a program of assistance is not continued, awareness of water management will gradually diminish.

PUMPING PLANT--EVALUATIONS

During the river basin study, 95 pump evaluations were completed. Of these evaluations 31 were electric pumps and 31 were natural gas pumps in Hidalgo County. Irrigation pump evaluations were well accepted in the study area and provided important information to the producers. Table 1 shows a summary of the evaluations in Hidalgo County.

Table 1. Irrigation Pump Evaluations				
Pump Type	Overall Eff. %	Pump Eff. %	Cost Per Ac.-In.	Potential Savings/Hour
Electric	38.4	45.8	4.99	2.39
Natural Gas	11.0	-	1.79	.79

PUMPING PLANT--EFFICIENCY

New Mexico State University (NMSU) currently has a program to test pumping plant efficiencies. These tests show that many pumps in the study area have low efficiencies.

Despite this documentation of low pump efficiencies, few pumps have been overhauled. This is apparently due to the cost of pulling a pump out of the well for servicing and the uncertainty that servicing the pump would improve efficiency.

During the study, the Black Range Resource Conservation and Development Corporation obtained a grant to cost share pump overhauls. The New Mexico Water Resources Research Institute assisted with grant administration. The grant was funded by the New Mexico Energy, Minerals, and Natural Resources Department.

Three pumping plants were overhauled with grant monies. Dr. A. W. Blair of NMSU's Civil, Agricultural, and Geological Engineering Department provided guidance for the overhauls.

Table 2 presents the cost of the pump overhauls and the expected payback periods. The payback period depends on the existing pump efficiency, the expected pump efficiency after overhaul, the amount of water pumped, and the cost of energy. The internal rate of return used in the following calculations is based on a 10-year period of analysis. The payback period calculations are based on a 10-percent rate of interest.

<u>Pumping Plant 1 (Electric)</u>: After this pump was pulled, it was determined that the primary reason for the low efficiency was improper pump design. The bowls were not designed for the required lift. Overhauling the old pump would not have improved its efficiency. After a redesigned pump was installed, pump efficiency increased from 47 percent to 82 percent. The flow rate increased from 239 GPM to 440 GPM, and the total pumping head increased from 134 to 192 feet. Increased drawdown due to increased GPM caused the change in pumping head.

The cost of pumping water decreased from $3.72 to $2.77 per acre-inch with the new pumping system. Energy use was reduced by 26 percent. Renovation cost $4,575, and a net savings of about $1,995 per year is expected. This investment will have a 42.3 percent internal rate of return. The payback period for this pump overhaul is two to three years.

<u>Pumping Plant 2 (Diesel)</u>: The drawdown was inaccurately determined in this well's original pump test. At about 159 feet below the top of the well casing, a large cascade of water was entering the well. The electronic depth sounder used to determine the

Table 2. Pumping Plant Repair Data	PUMP NUMBER 1	2	3
Pumping Plant Efficiency			
Before	47.0%	43.0%	49.0%
After	82.0%	74.0%	72.0%
Discharge or Flow Rate			
Before (gpm)	239	626	273
After (gpm)	440	726	560
Bowl Depth			
Before (feet)	134	159	121
After (feet)	192	266	151
Drawdown Depth			
Before (feet)	130	147	117
After (feet)	170	253	134
Water Cost per Acre Foot			
Before	$40.60	$27.40	$35.60
After	$33.20	$21.30	$28.48
Length of Stem Pulled			
Feet	250	290	180
Repair Cost			
Pull Pump and Replace	$1,300	$1,525	$950
Bowl Repair	$2,400	$2,400	$2,400
Labor at Shop	$125	$250	$250
Parts, Misc.	$750	$750	$750
	------	------	------
Total	$4,575	$4,925	$4,350
Annual Pumping Cost			
Before (dollars)	$4,400	$4,820	$4,400
After (dollars)	$2,405	$4,167	$2,171
Annual Savings			
Dollars	$1,995	$653	$2,229
Years to Pay Back Capital Based on 10% Interest (years)	2-3	14-15	2-3
Rate of Return on Investment Based on 10-year Period of Analysis	42.3%	5.5%	50.3%

NOTE: The annual pumping cost figures are based on the following data:
Pump 1--88.3 acre-feet per year;
Pump 2--232 acre-feet per year; and
Pump 3--102 acre-feet per year.

drawdown level mistook this cascade for the water surface. A water surface access tube was installed in the well when the pump was replaced. This tube prevented the cascade from interfering with the depth sounder during the post repair pump test.

The large cascade entrains air in the pumped water. The entrained air reduces the performance of the pump. As shown in Table 2, the benefits of repair of this pump were equal to the cost of repair. However, the cost per acre-foot was decreased by 22 percent, and the flow rate was increased by 16 percent. The cost of the changes was $4,925. The annual savings are estimated at $653, which generates a 5.5 percent internal rate of return. The payback period for this investment is estimated at 14 to 15 years.

Pumping Plant 3 (Electric): This pump was found to be worn out by sand and age. The pump was rebuilt and installed. As a result, the original efficiency increased 23 percent, and the discharge almost doubled. Overall, this was the most successful demonstration of the potential energy savings which can be achieved by repairing a pump. The repair cost for this pump was the lowest of the three pumps repaired. The increase in drawdown due to increased discharge was also the lowest. The cost per acre-foot of water decreased by 20 percent. The repair cost was $4,350, which resulted in a savings of about $2,229 per year. This renovation resulted in a 50 percent internal rate of return on the investment, and the payback period will be less than three years.

Summary: Pump 1 was replaced with a new pump instead of being overhauled. However, even with replacement, the renovation has a payback period of two to three years. Pump 3 was overhauled, and the cost of renovation will be repaid in two to three years. Pump 2 was improved slightly through renovation. Pump 2 represents the risk involved in pulling a pump out of the ground. This situation may also be true of other pumps in the study area.

Renovating your pumping system could decrease irrigation costs, so check the efficiency of your pumping plant. You can request a pump evaluation from the Soil Conservation Service or from the Agricultural Engineering Department at New Mexico State University.

PUMPING PLANT--CONVERSION OF POWER SUPPLY

Another way to reduce cost is to convert power supply at the irrigation pump. Currently, it is less expensive to use diesel or natural gas than to use electricity. Six to twelve landowners in the study area were interviewed about their conversions. Two landowners had excellent results from changing from electricity to diesel power. Following are case studies of these two landowners conversions.

Case Study 1: Information gathered from the landowner shows that 10 to 12 pumps were converted from electricity to diesel fuel. Most of these were 100-horsepower electric motors that were converted to 200-horsepower diesel engines. The lift for these wells averaged about 180 feet. The cost of a new diesel engine was about $16,000. Comparable new electric motors would cost $4,100. The diesel engines will need to be overhauled twice in the ten-year period at a cost of $6,000 per overhaul. A small replacement cost has been calculated for the electric motors to anticipate the chance of lightning damage. The operation and maintenance cost of the diesel engine was estimated at $7.81 per hour ($1.95 per acre-inch at 1,800 GPM). Comparable cost for the electric motor would be $19.50 per hour ($4.87 per acre-inch). The operation portion of these costs is the actual fuel charge to operate these motors per hour. The maintenance cost includes normal upkeep items. These figures are based on an average year of 2,000

hours of pumping time. This conversion would result in a savings of $20,402 per year, or a 51 percent reduction in total operating costs. Under current conditions for this particular farmer, these changes will result in a payback period of less than one year.

Case Study 2: This farmer converted the 40-horsepower electric motor on his well to a 60-horsepower diesel engine. The lift for this well was about 120 feet. The cost of the new diesel engine was approximately $5,500. The replacement cost of the existing electric motor is about $1,945. The diesel engine will be overhauled twice within the ten years at a cost of $4,000 per overhaul. The operation (fuel cost) and maintenance cost of the diesel engine was estimated at $1.08 per acre-inch ($1.44 per hour at 600 GPM) of pumped water. The operation and maintenance cost would be $2.13 per acre-inch ($2.84 per hour) for the electric motor. Based on an average operating time of 2,000 hours per year, operation and maintenance costs would be $3,244 for the diesel engine and $6,390 for the electric motor. This conversion will reduce the total annual cost from $6,745 per year to $4,887 per year. This change creates net benefits of $1,858 per year and reduces operating costs by 28 percent.

Summary: Table 3 summarizes the costs and savings of each conversion. The costs have been annualized at a 10-percent discount rate for a period of ten years. Though ten years is a short period of analysis, it was used because of the constant change in fuel price.

Table 3. Annual Cost Summary (Dollars) 1/

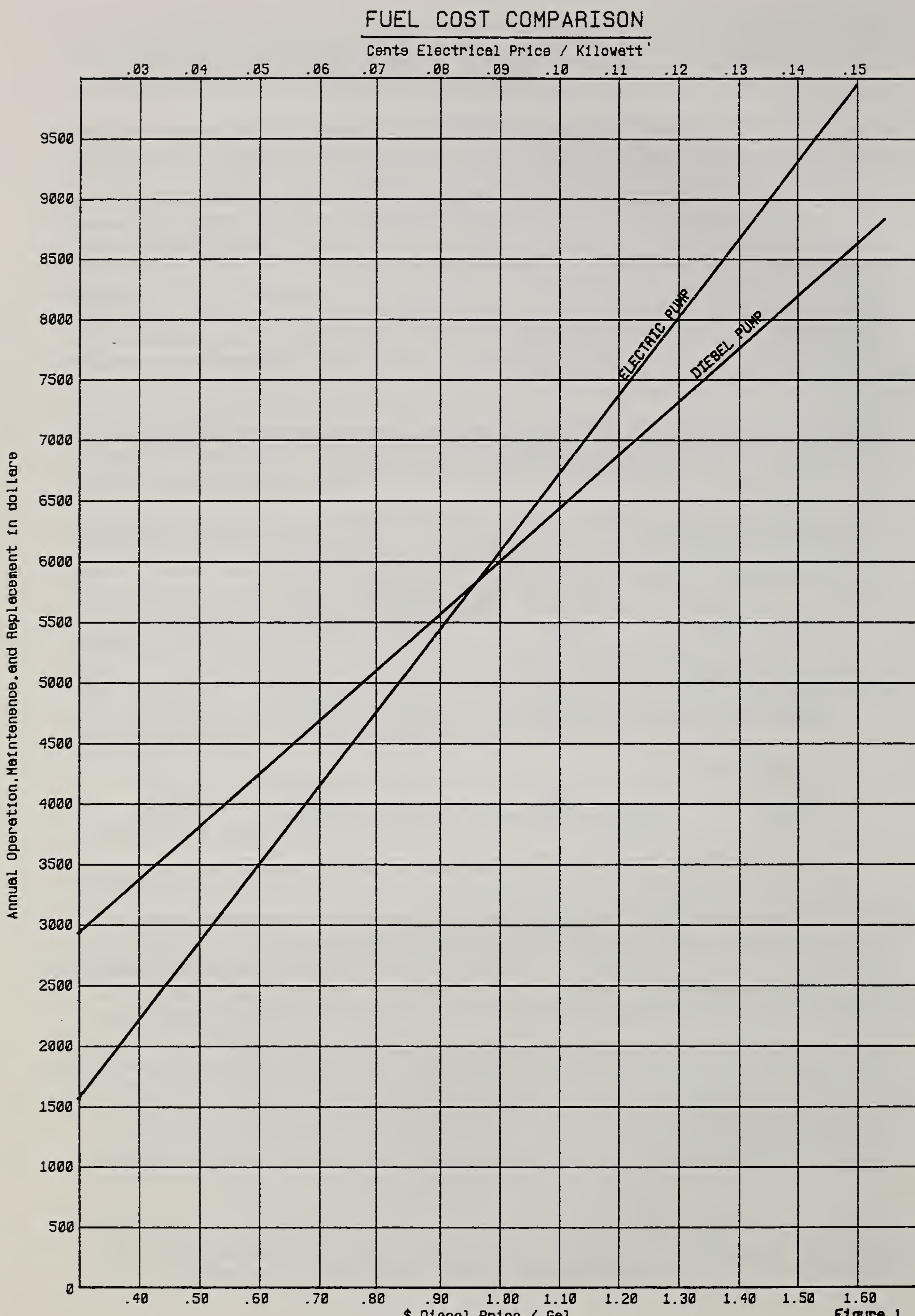
Power Source	Motor Cost	Replacement Costs	Annual O&M	Total Annual Cost
Case Study 1				
Electric	667	82	39,000	39,749
Diesel	2,604	1,122	15,621	19,347
Case Study 2				
Electric	316	39	6,390	6,745
Diesel	895	748	3,244	4,887

1/ Annualized at 10-Percent Discount Rate for 10 years.

Based on the experiences of these two farmers, it is apparent that, presently, pumping cost can be greatly reduced by converting from electricity to diesel. There is also potential to convert from electricity to natural gas. Comparisons of diesel and natural gas show that the pumping cost, operation and maintenance cost, and conversion cost are similar. The choice between diesel and natural gas is a matter of farmer preference.

However, conversions may not always be profitable. If the price of diesel increased from the current level of 60 to 70 cents per gallon to $1.15 to $1.25 per gallon, savings would be marginal. Most farmers who have converted to diesel are keeping their electric motors to protect against diesel price increases. If the price of diesel reaches the breakeven point ($1.15 to $1.25 per gallon), farmers can revert to electricity quickly. With current fuel prices, conversions should be considered.

Figure 1 illustrates how the cost of fuel affects the operation and maintenance cost of irrigating. Case Study 2 was used in this illustration, because it is representative of a large number of similar pumps in the study area. Table 3 shows the operation,



FUEL COST COMPARISON
Cents Electrical Price / Kilowatt
.03 .04 .05 .06 .07 .08 .09 .10 .11 .12 .13 .14 .15
Annual Operation, Maintenance, and Replacement in dollars
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500
ELECTRIC PUMP
DIESEL PUMP
.40 .50 .60 .70 .80 .90 1.00 1.10 1.20 1.30 1.40 1.50 1.60
$ Diesel Price / Gal.

Figure 1

maintenance, and replacement (OM&R) costs for a 40-horsepower electric pump and a 60-horsepower diesel pump. The annualized replacement cost and salvage value of the pumps are included in this table. If the price of diesel is 95 cents per gallon and the price of electricity is 8.5 cents per kilowatt, then the OM&R costs are $5,750 for both types of fuel. This table can be used as a guide for decisions to change power sources based on current market prices. (The table is based on 2,000 hours of pumping time per year at a rate of about 1.5 acre-inches per hour. The costs are annualized at a 10-percent discount rate for a period of ten years).

APPLICATION OF WATER--IRRIGATION SCHEDULING

Profitable irrigated farming requires water management based on the latest technologies. The first step in this process is proper scheduling, applying water at the proper time to meet the needs of the plant.

A major finding of the study was the importance of irrigation scheduling, especially on moisture sensitive, shallow rooted crops, such as chile and onions. It was found that production could be substantially increased by proper scheduling. With few exceptions, increases occurred with less water or with the same amount of water.

The study found that irrigation scheduling in the area was based on a set time period. In many cases, this set time period did not meet the needs of the crop and production losses occurred. Scheduling instruments were found to eliminate untimely irrigations and over-watering.

Acreages of chiles and onions in the study area have increased substantially in the last two years. These crops are more sensitive to soil moisture changes, because they have a shallow root system. They draw moisture from a small volume of soil. Timely irrigations of these crops is important to minimize stress and yield reductions.

Tensiometers worked well on the cotton, alfalfa, milo, barley, chile, and onion crops. One farmer irrigates barley with center pivot sprinklers. Using tensiometers to schedule irrigations, he produced 8,100 pounds per acre in 1988. The county average is about 3,600 pounds per acre. Tensiometers indicated that one farmer was not irrigating his chile often enough. The crop was getting its moisture only from the six to 12-inch root depth. Tensiometers indicated that an alfalfa crop was getting most of its moisture from the 12 to 24-inch depth. Even though the rest of the root zone was moist, the alfalfa appeared dormant. It used little or no water for about 10 days after cutting. This 10-day loss of growth reduced the season's production.

One farmer had five fields of cotton. The highest yield was produced in the only field with tensiometers. Another Luna County farmer used tensiometers and harvested 200 sacks of onions per acre more than the county average. After tensiometers were installed in early April, he decreased irrigations from one per week to one every two weeks. Irrigation intervals then changed according to the consumptive use of the crop. A first-time onion producer produced 1,300 sacks of midseason onions, and 60 percent of the harvest graded as colossal onions. He depended exclusively on tensiometers for irrigation scheduling.

One farmer in the Virden area who had traditionally irrigated on a weekly schedule could not believe his tensiometer readings. They showed that the soil was dry in the 18 to 36-inch zone. After soil probing verified the readings, he knew that water was not penetrating to the lower half of the root zone across the bottom end of the field.

Tensiometers and gypsum blocks gave reliable readings for cotton throughout the season and indicated the zone from which the crop was getting its water.

Gypsum blocks, although valuable, are not as sensitive as tensiometers. They worked fairly well on cotton and corn, but did not forecast irrigation needs on chile and onions. Reaction time was too slow on these moisture sensitive crops.

Summary: Generally, the scheduling instruments indicated that farmers were over-irrigating early in the growing season and under-irrigating later in the season during the higher consumptive use period. In addition, after the summer rains began, crop beds and furrows became water soaked. The tensiometers indicated that irritation water was not reaching the portion of the root zone from which the plants were pulling moisture.

Under full irrigation conditions, tensiometers proved to be an excellent tool for scheduling irrigations. However, under limited or deficit irrigation, gypsum blocks were more effective in soil moisture monitoring and scheduling irrigations. Tensiometers are more adapted to high moisture levels and sandier soils. Low moisture conditions and heavier soils will cause tensiometers to function improperly.

Gypsum blocks are slower to respond after installation, and their readings generally lagged behind the tensiometer readings.

Figure 2 and Figure 3 show the actual readings of tensiometers and gypsum blocks, respectively, in an onion field and in a cotton field.

Following are advantages of using tensiometers and gypsum blocks:

1. Help to schedule timely irrigations. The farmer can cultivate and irrigate before suffering serious losses in production. Scheduling also helps to prevent overwatering or irrigating before it is needed.
2. Indicate the relative water holding capacity and drainage characteristics at different depths of the soil.
3. Indicate the depth of penetration after an irrigation or a rain.
4. Show the depth from which the crop is drawing moisture during different stages of growth and root development.
5. Determine the amount of readily available moisture. The readings can be used along with a field test of soil moisture to determine the amount of water needed to fill the root zone and the amount of water applied during an irrigation.
6. Recognize changes in crop consumptive use due to crop maturity and weather. They indicate the effects of cool, cloudy days as well as hot, windy days.

The study found that tensiometers are a good investment, regardless of the type of irrigation system. Every crop and every field should have its own set of scheduling instruments. Tensiometers should last at least five years with maintenance and care.

The study found that a soil probe is necessary to verify instrument readings and to check the adequacy of an irrigation.

SEASONAL TENSIOMETER READINGS

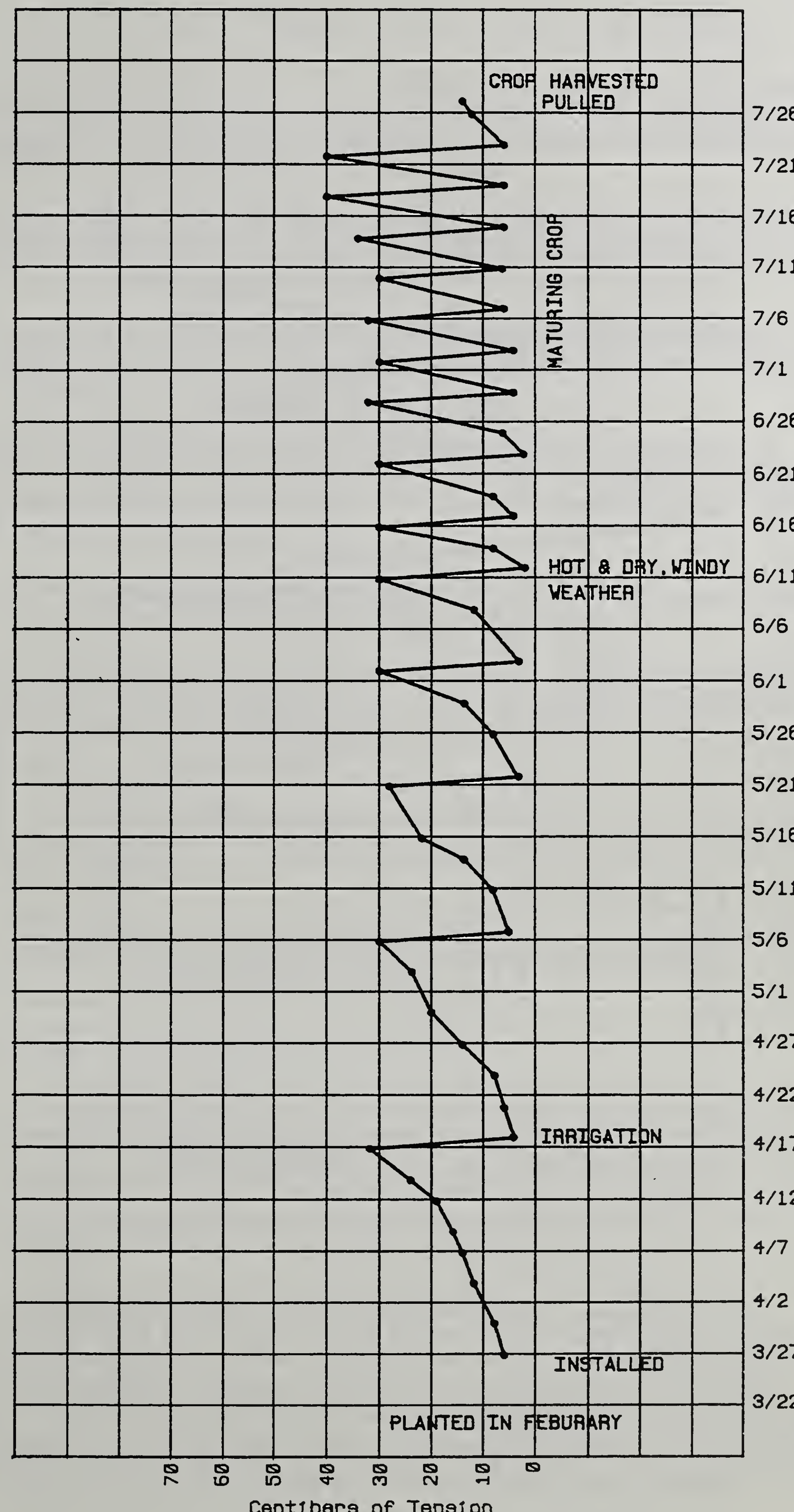
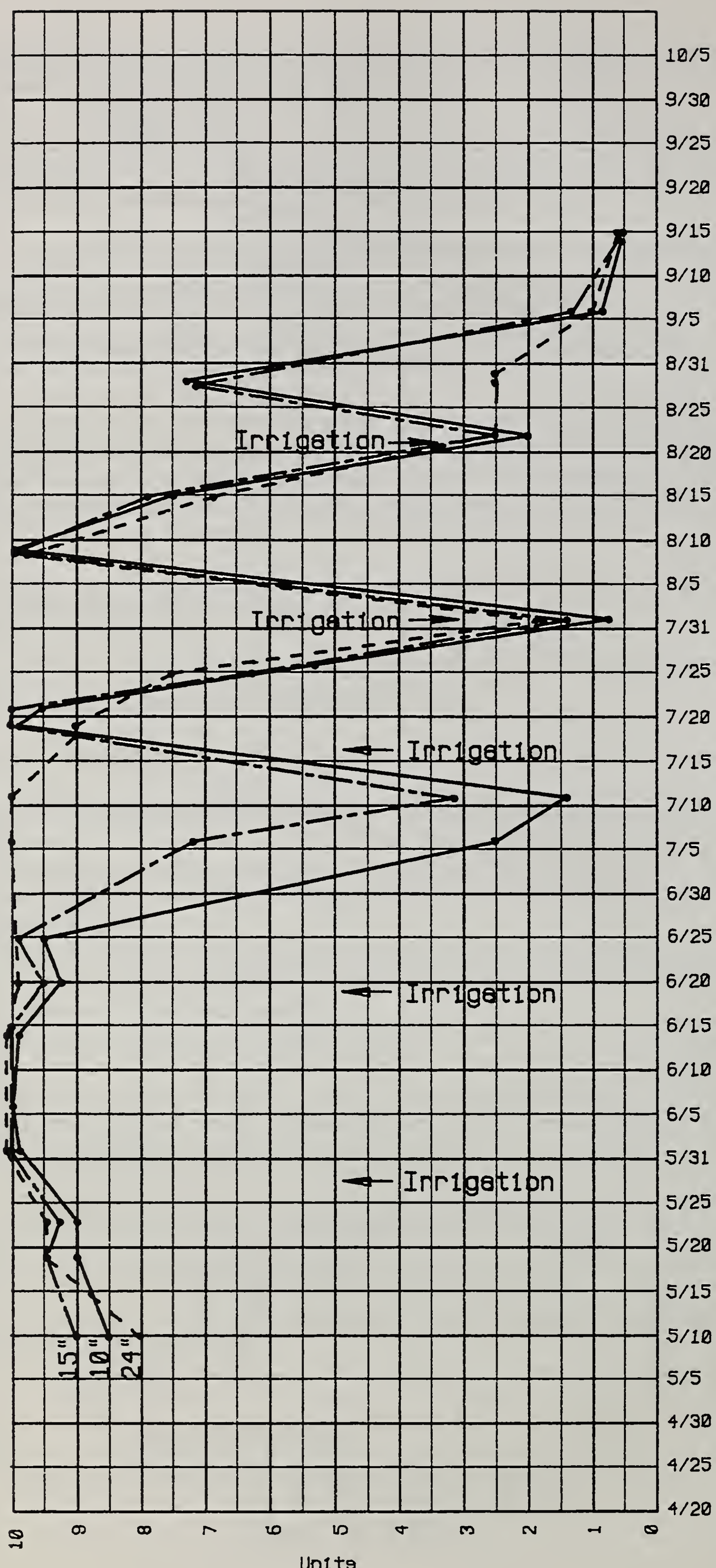


Figure 2

Spring planted onions

SEASONAL GYPSUM BLOCK READINGS



Cotton

Figure 3

APPLICATION OF WATER--OVERALL APPLICATION EFFICIENCY

The second step is to improve the efficiency of applying irrigation water. The present system must be managed at its highest efficiency. Once the present system is performing at its best, alternative systems or improvements can be compared to it. Decisions can then be made whether or not to change the present system.

Overall application efficiencies in the study area varied from as low as 10 percent to as high as 90 percent. Table 4 shows the range of application efficiencies that can be expected with the installation of conservation practices.

Table 4 indicates that graded surface systems had the widest range of efficiencies. This range is dependent on the crop, soil, slope, length of run, and management. Discussion of these factors follows.

Crops: Shallow rooted crops have the lowest efficiencies due to the difficulty in applying a shallow irrigation without deep percolation losses. Even though the efficiency is lower for shallow rooted crops, the amount of water applied per irrigation is usually lower than that applied on deep rooted crops.

Soils: Efficiencies were higher for slow intake soils than for high intake soils. Deep percolation losses are lower in slow intake soils than in high intake soils.

Slope: Furrow slope varied from 0.1 percent to 0.5 percent. Steeper slopes had lower efficiencies because of tailwater runoff or deep percolation losses at the upper end. Deep percolation losses occurred when the furrow flow rate was slowed to keep tailwater losses to a minimum.

Length of Run: The longer the field was, the lower its efficiency was. Deep percolation losses occurred at the upper end. Some producers have increased efficiency just by cutting a long field in half.

Management: Regardless of the type of irrigation system, it must be managed. Use of proper management techniques can reduce irrigation cost by 10 to 30 percent.

APPLICATION OF WATER--CENTER PIVOTS

Center pivot systems demonstrated better water use efficiencies and energy savings than other irrigation systems evaluated during the study. Data collected during the study shows that center pivot sprinklers are operating at an overall efficiency of 61.8 percent. In comparison, graded furrows, level basins, and graded borders had an overall irrigation efficiency of 44.2 percent. The average cost per acre-inch of water applied was $1.86 for center pivots compared to $2.38 per acre-inch for graded systems.

Center pivots were found to operate successfully at seven to eight GPM per acre compared to 10 to 12 GPM per acre for graded systems. This comparison represents a water savings of 20 to 33 percent. The average center pivot system was operating at 6.3 GPM per acre. Assuming the system is operated 24 hours per day at 61.8 percent efficiency, there would be sufficient water to meet the consumptive crop use demand of 0.21. This amount will not adequately irrigate most crops grown in the study area in dry years. Farmers should adjust planted acreage to stay within the seven to eight GPM per acre range.

Table 4. Application Efficiencies

Conservation System	Efficiency Range
Conventional Slope--Land Planed Graded Furrow System (Present Condition)	
Deep Rooted Crops	.20-80%
Shallow Rooted Crops	15-30%
Conventional Slope--With Surge 1/	
Deep Rooted Crops	.40-80%
Shallow Rooted Crops	30-55%
Modified Slope	
Deep Rooted Crops	.30-75%
Shallow Rooted Crops	20-40%
Modified Slope- With Surge 1/	
Deep Rooted Crops	.45-80%
Shallow Rooted Crops	30-65%
Level Basin	
Deep Rooted Crops	.40-80%
Shallow Rooted Crops	30-65%
Level Basin- With Surge 1/	
Deep Rooted Crops	.45-80%
Shallow Rooted Crops	35-65%
Sprinkler System	
Deep Rooted Crops	.55-80%
Shallow Rooted Crops	55-80%
Drip System	
Deep Rooted Crops	.60-90%
Shallow Rooted Crops	60-90%

1/ A surge system should only be used on 0.3 or 0.5 intake soils. It should be used on 0.1 intake soils only under special conditions.

NOTE: Higher efficiencies of surface systems generally occur on 0.1 intake soils, because less water is lost to deep percolation in slow intake soils.

Farmers reported that annual labor needs for center pivots was 0.5 hours or less per irrigated acre. Graded systems with gated pipe or siphons require 1.5 to two hours per acre.

Average yields for crops grown under center pivot irrigation were usually higher than those reported for crops grown under graded systems. Refer to Table 5 for comparison data.

Farmers reported that application of chemicals, such as fertilizer and pesticides through center pivots cost approximately 50 cents per acre. This amount compares to $3.00 to $3.50 per acre to apply these chemicals with a tractor, and $5.00 to $8.00 per acre using aerial applications. Uniformity of chemical application through center pivots has been found to equal that of tractor or aerial applications. However, chemicals can be applied only as uniformly as the system's pattern efficiency. Pattern efficiency is the ability of the system to sprinkle water evenly across the field.

Table 5. Comparison of Yields

Crop	Units	Center Pivot	Graded Furrow
Cotton	lbs. per acre-inch	29	18
Corn	bu. per acre-inch	5.75	3.36
Milo	lbs. per acre-inch	316	197
Chile	lbs. per acre-inch	125	56

Soil probes on loamy sand and loamy soils found that uniformity corresponds with the pattern efficiency. However, on silty clay loam and sandy clay loam soils, uniformity varied as much as 50 percent from pattern efficiencies. The only way to determine if an irrigation filled the root zone was by probing and using soil moisture monitoring devices, such as tensiometers or gypsum blocks.

Center pivot big guns (or volume gun at the outside end) were found to be inefficient in applying water. The operation of a big gun can be sporadic. A big gun uses about 15 to 20 percent of total water applied, taking water away from the rest of the pivot and decreasing the efficiency of the whole system. In addition, the acres irrigated by the big gun produces only about 10 percent of the total crop.

PRE-PLANT IRRIGATION

Pre-irrigation evaluations conducted during the study showed an overall average efficiency of 30 to 40 percent. Factors affecting pre-irrigation efficiency were the plowing method, size of clods (texture), row spacing, depth of beds, previous crop grown, and slope of the field. Fields with more clods did not seal off, and water soaked across the rows faster. Deep ripped fields absorbed water faster, which caused slower advances. The water soaked deep in the soil rather than across the beds. Tire packed furrows had faster water advance, and beds were soaked at the lower end of the field sooner. Fields that were previously in wheat, corn, milo, and other high stubble crops were harder to pre-irrigate because of stubble and porous soil.

The highest pre-irrigation efficiencies resulted when farmers irrigated every other row, using 20 to 30 GPM per furrow on loamy sand and loamy soils and 15 to 20 GPM per furrow on clay loam or silty clay loam soils with 1,200 to 1,300-foot runs and twelve-hour sets.

Using surge irrigation and larger flows per furrow improved advance times on pre-irrigation by as much as 50 percent. Fields were more uniformly irrigated with less deep percolation losses on the upper end of the field and better penetration on the lower end of the field.

CHANGING OR IMPROVING YOUR SYSTEM

You should consider application efficiency and uniformity efficiency when evaluating a new system or improvements to your existing system. Also consider the kinds of crops to be grown and your soil type. These factors will affect the cost and return of contemplated alternative systems and improvements.

An improvement or installation of an alternative system may require a higher level of management to realize the anticipated reduction in cost or improved yield. This change in management must be considered as a cost or as a commitment of time and knowledge.

CHANGES TO THE PUMPING PLANT

If you want to overhaul your pump, you should conduct a pumping plant evaluation or efficiency test to determine the actual and expected efficiency of the pumping plant. Table 2, Pumping Plant Repair Data, can be used to estimate the possible payback period. Have a reputable repairman estimate the cost of overhauling the pump.

A pump overhaul includes repairing or replacing the impellers, bowls, bearings, and bushings. Portions of the driveshaft, tubing, and column pipe may also be replaced. A poorly designed pump may need to be replaced, which may not result in a higher cost (See Table 2).

CHANGES TO THE ON-FARM CONVEYANCE SYSTEM

If you use an earthen ditch for conveyance, you should replace it with a concrete lined ditch or underground pipeline. An underground pipeline is the most efficient method of conveyance and will outlast two or three concrete ditch linings. As a minimum, the distance from the pump to the point of delivery in the field should be underground PVC pipe. You can use either concrete lined ditch or gated pipe beyond the point of delivery.

CHANGES TO THE FIELD APPLICATION SYSTEM

The typical system in the study area consists of land planed graded furrows with a length of run of one quarter mile and a furrow slope between 0.1 and 0.3 feet per 100 feet. The cost of irrigation for this system ranges from $75 to $175 per acre.

It is difficult to measure all of the effects of changes or improvements. A variety of improvements and conservation practices were applied as part of this study. Table 6 gives a summary of the costs of applied practices. The table also provides guidelines on where and when each practice would be most beneficial and which soils are most compatible. In addition, the effect of each practice on production levels is estimated. However, because of the number of variables, it is difficult to determine the change in yield or cost of production due to the conservation practice or improvement. The savings in irrigation costs for each practice were based on the cost per acre of the existing system.

Laser grading puts a more exact grade on a field than conventional land planing. On fields that are irrigated by a surface system, laser leveling is recommended. This practice

will make water management easier, and the water advances in the furrows will be more uniform.

In a modified slope graded system, the upper two-thirds of the length of the field is sloped and the lower one-third of the field is graded to level. A modified slope with its flatter section at the bottom third acts as a ponding section. The water in fast advancing furrows will turn and flow back up adjacent furrows to meet the water in slower advancing furrows. This action shortens irrigation time and greatly increases uniformity.

A modified slope can increase the overall efficiency by increasing uniformity. However, the irrigation must be stopped before the bottom end is flooded to compensate for the water that is still in the upper section of the furrows.

To install a modified slope, lower the plane of the upper two-thirds of the field and use the soil from the upper end to raise the bottom third to a flatter grade. The bottom end will normally have a finished grade of 0.05 feet per 100 feet (0.05 percent). There is no specific formula for determining the grade at the bottom end. However, experience has shown that a 0.05 percent grade works best when the grade of the upper two-thirds ranges from 0.1 to 0.3 percent.

Two level basins were installed with the grant monies. One level basin did not have a sideslope. The other had a sideslope of 0.3 feet per 100 feet. Sideslope flow was controlled by small check dams at the end of the furrow at 10-row intervals. Both level basins had a grade along the furrow of 0.03 feet per 100 feet. The length of the furrows for both basins was 600 feet.

Both basins worked well. Level basins should work best on slow intake soils. These soils have intake rates of 0.1 and 0.3. Level basins may also work on soils with an intake rate of 0.5. However, for these soils, the furrow grade should be increased to 0.05 feet per 100 feet.

A major advantage of the level basin system is the lateral movement of moisture into the bed. Another advantage is the uniformity of water penetration along the length of run. The application efficiency is highly dependent on the GPM per furrow. For level basins, a high rate of flow (GPM) per furrow must be used. This rate fills the furrow quickly. On these two level basins, 30 GPM per furrow was used. This flow rate worked well.

Level basin irrigation may take on added emphasis in the future as the acreage of vegetable and specialty crops increases in the study area.

The expense of installing a level basin depends on the amount of soil to be moved, which can be a substantial amount on slopes of 0.2 feet per 100 feet and higher. In addition, if a field is cut in half to install level basins, an additional conveyance and delivery system will be needed.

A surge irrigation system is highly recommended if: (1) you already irrigate with gated pipe, (2) your soil has an intake rate of 0.3 or higher, (3) the furrow slope is 0.3 feet per 100 feet or less, and (4) the length of run is greater than 600 feet. This recommendation is even more important for shallow rooted crops.

A surge system normally consists of a controller unit and two valves with gated pipe. The controller unit can be used on one valve and a set of gated pipe while that set is being irrigated. When the first set is almost irrigated, the controller is moved to the second valve. The water is then switched to the second valve or set. While the second

Table 6. Cost and Effects of Conservation Practices			
Conservation Practice	Average Cost/Acre	Comments on Installation and Usage	Irrigation Cost/Acre Before Installation 1/
Modified Slope	$125-250	Costs will vary depending on slope, field length, depth of cut, soil conditions, and design grade.	$75-175
Level Basin Level Basin with Conveyance System	$150-550 $300-700	Costs will vary depending on slope, field length, depth of cut, soil conditions, and design grade. If a field requires dividing in half, a Conveyance System will need to be installed for the lower portion of field. An additional turn road will be needed.	$75-175 $75-175
Surge System One Controller and Two Valves (Automated Solar Powered)	$30-40	Average cost per acre is based on $1600 for one controller and two valves. Must have a gated pipe field delivery system for a Surge System.	$75-175
Center Pivot	$290-350	Costs are based on 1300 Ft. length Center Pivot that can irrigate 122 acres.	$75-175
Center Pivot: Conversion to LEPA 2/	$28-30	Costs are based on 1300 Ft. length Center Pivot that can irrigate 122 acres.	$75-175
Drip System	$1000-1200	Most economical use would be on high value crops.	$75-175
Tensiometers Gypsum Blocks	$1.00-2.00 $1.00-2.00	Use on sandy loam to silty clay loams. Highly recommended for shallow rooted crops. Most effective on crops tolerant of moisture related stress.	$75-175 $75-175
Infrared Gun	$5000 Each	Use on Infrared Programmed Crops.	$75-175

1/ Based on Conventional System which is a graded furrow system--land planed, quarter mile long runs, and furrow slope ranging from 0.1 to 0.3 foot per 100 feet)

Table 6. Cost and Effects of Conservation Practices (Continued)	
Irrigation Savings/Acre After Installation	Comments on Production and Water Savings
10-20 %	Production may be decreased the first year at the upper end of the field depending on the amount of soil removed during construction. Overall production should increase due to higher uniformity of penetration of irrigation water. Modified slope saves irrigation time by allowing fast furrow advances to circle back to meet the slower furrow advances and increase the opportunity time of the slower advances. Modified slope also saves labor costs used for adjusting irrigation syphon hoses.
10-30 % 10-30 %	Production may be decreased the first year at the upper end of the field depending on the amount of soil removed during construction. Level Basin Systems are more applicable on shallow rooted vegetable crops. Due to pump capacities, Level Basin is not recommended for fields longer than 600 feet without Surge Irrigation. Level Basin can aid in wetting beds on slow intake rate soils. Overall production should increase.
10-40 %	Excellent results were found on 0.5 intake rate soils. Satisfactory to excellent results were found on 0.3 intake rate soils depending on soil and furrow conditions. Generally not recommended on 0.1 intake soils due to slow infiltration rate. Surge is highly recommended on fields that have 0.3 and 0.5 intake rate soils and an existing gated pipe delivery system. Overall production should increase.
20-40 %	Additional costs may be incurred such as installation of high pressure pipelines. Application efficiencies of Center Pivots are high; however their overall efficiency will depend on the uniformity of application of water by the nozzles. Poor uniformity of nozzle application was found to be a common problem in the area.
30-50 %	This cost is the cost of converting an existing Center Pivot to a LEPA System. On fields with steep slopes it may be advantageous to use row dikers to control runoff. Center Pivots and Center Pivot LEPA Systems can also be used to apply fertilizer and pesticide.
10-20 %	Drip Systems would be more applicable on high value crops, such as vineyards, and establishing orchards.
10-20 % 10-20 %	No field should be without its set of Tensiometers or Gypsum Blocks. These are the most economical Water Conservation Practices. Irrigation Scheduling makes a substantial difference in yields, especially on shallow rooted vegetable crops. The greatest success in this study was through these practices.
10-20 %	An Infrared Scheduling Gun would be more applicable on large acreages due to its high initial cost.

2/ LEPA means Low Energy Precision Application
Note: All the Conservation Practices listed above will have a positive affect on production levels.

set is being watered, the valve and gated pipe from the first set are moved forward and placed for the next set.

A surge system will save water on most pre-plant irrigations as well as later irrigations. The greatest water savings, for one irrigation, was 55 percent on an onion crop. A water savings of 50 percent was measured on both a growing chile crop and a pre-emergent wheat crop.

Combining surge irrigation with other practices was effective in decreasing irrigation costs and increasing uniformity. The use of surge irrigation with a conventional or modified slope was effective in reducing water requirements and pumping cost. Table 7 shows the effects of surge irrigation on a field with a conventional slope. The figures are compared to the same field without surge irrigation.

Table 7. Surge Data Per Irrigation Application

Crop	Existing System 1/ (Ac.In)	Surge System (Ac.In)	Water Saved (Ac.In)	Average Cost 3/ ($/Ac.In)	Savings Per Acre ($/Ac.)	Savings Per Acre (Percent)
Chile 2/	10.80	9.40	1.40	2.20	3.08	13.0
Chile 2/	8.50	8.50	0.00	2.20	0.00	0.0
Chile 2/	9.00	4.80	4.20	2.20	9.24	46.7
Chile 2/	10.60	9.80	0.80	2.20	1.76	7.5
Chile	6.30	4.90	1.40	2.20	3.08	22.2
Chile	6.50	6.50	0.00	2.20	0.00	0.0
Chile	5.20	3.90	1.30	2.20	2.86	25.0
Cotton 2/	12.00	9.10	2.90	2.20	6.38	24.1
Cotton 2/	10.30	7.80	2.50	2.20	5.50	24.3
Cotton 2/	9.80	9.80	0.00	2.20	0.00	0.0
Cotton 2/	11.40	8.00	3.40	2.20	7.48	29.8
Cotton	5.20	2.90	2.30	2.20	5.06	44.2
Cotton 2/	14.02	11.39	2.63	1.10	2.89	18.8
Cotton 2/	14.02	11.01	3.01	1.10	3.31	21.5
Cotton	4.65	2.60	2.05	1.10	2.26	44.1
Cotton	5.52	2.76	2.76	1.10	3.03	50.0
P.Bean	5.78	5.43	0.35	2.20	0.77	6.1
P.Bean	5.78	5.18	0.60	2.20	1.32	10.4
Onions	6.10	2.70	3.40	2.20	7.48	55.7
Spinach	4.90	2.40	2.50	2.20	5.50	51.1
Spinach 2/	7.54	7.26	0.28	2.20	0.62	3.7
Wheat 2/	12.80	8.23	4.57	2.20	10.05	35.7
Wheat 2/	12.80	6.23	6.46	2.20	14.21	50.5
Wheat 2/	12.80	6.75	6.05	2.20	13.31	47.3
Wheat 2/	12.80	7.55	5.25	2.20	11.55	41.0
Average	9.00	6.61	2.40	2.02	4.82	27.0

1/ Existing system is defined as a graded furrow with a quarter-mile run and a slope range of 0.1 to 0.3 feet per 100 feet.
2/ Done as a pre-irrigation application to prepare the seedbed for planting.
3/ Average cost per acre-inch for the area based on energy source ($2.20 used for electricity; $1.10 used for diesel; and $1.10 used for natural gas.)

Each of the evaluations shown in Table 7 are side-by-side comparisons made before and during the growing season. The greatest documented savings of water (55.7%) was for surge on an onion crop. The soil had an intake rate of 0.3. This savings should not be expected for each irrigation. However, a 30 to 40 percent water savings per acre per season is realistic for vegetable crops. The greatest savings would be on shallow rooted crops because of the number and the shallow depth of irrigations during the season. For deep rooted crops, such as cotton, on a loamy soil, a 20 to 30 percent water savings can be expected.

No significant water savings were measured in three of the comparisons. These plots had an uncommon soil type. They were extremely dry silty clay loam soils pulverized by pre-plant tillage operations. Under these conditions, the soil surface seals and water does not penetrate below the surface. It is difficult to irrigate these soils with either surge or conventional systems. In this unusual situation, no water savings is expected to occur when surge is used.

Center pivot sprinklers normally have an 85 to 90 percent application efficiency. Uniformity depends on the nozzle package. A center pivot is normally available in lengths that will irrigate a quarter section of land. However, shorter lengths are also available. This system requires a high pressure pipeline to the center of the field. Small plots of 10 to 20 acres generally do not warrant the investment required for a center pivot. A center pivot system would be cost effective for alfalfa or corn crops of over 100 acres. These crops can be grown with less water due to the higher application efficiency. Higher production can also be expected.

Table 8 can be used as a guideline to help irrigators determine which conservation practices are recommended on each different soil intake group.

Table 8. Recommended Treatment

Conservation System	Shallow Rooted Crops Soil Intake Rate .1	.3	.5	Deep Rooted Crops Soil Intake Rate .1	.3	.5
Water Management	H	H	H	H	H	H
Irrig. Scheduling	H	H	H	H	H	H
Modified Slope	H	H	H	H	H	H
Level Basin (600 Ft.)	R	R	N	R	R	R
Conventional w/Surge	R	H	H	N	R	H
Mod. Slope w/Surge	R	R	H	N	R	H
Level Basin w/Surge	N	N	R	N	R	H
Center Pivot 1/	R	R	R	R	R	R
Center Pivot Converted to LEPA 1/	R	R	R	R	R	R
Drip System 2/	R	R	R	R	R	R

Legend: (H) Highly Recommended
(R) Recommended
(N) Not Recommended

1/ Center pivot systems have more field constraints than the other systems.
2/ Drip systems are expensive and recommended only for specialty crops.

ALTERNATIVE CROPS

The following alternative crops were evaluated: chile, onions, Afghan pines, pecans, spinach, grapes, and pinto beans. The list was limited to crops with good potential for production and marketing. The list, however, could have been much longer, because the climate, soil, and length of growing season could support a large variety of crops. The limiting factor is market availability.

A list of consumptive use, or evapo-transpiration, rates of these crops was developed. This information has been added to the Irrigation Guide in the Deming and Lordsburg Field Offices of the Soil Conservation Service. The information and interpretations for its use are available from these offices.

Crop budgets for these crops have also been developed. These have been added to "Section I" of the Field Office Technical Guide. This information and interpretations for its use are also available from the Deming and Lordsburg offices.

At this time, the most viable alternative for idle cropland is high value row crops. Since 1988, some idle land has been planted to chile, onions, and spinach.

Summary: Costs for specialized equipment and labor, as well as the availability of markets, should be considered in deciding whether to grow new or alternative crops. Another factor to consider is crop rotations to maintain soil tilth and reduce the frequency or severity of disease. Experience has shown that organic matter in the soil decreases rapidly, and the incidence of disease sharply increases. Small grains can be used in rotation to help solve this problem.

Producers can expect yields of 8 to 10 tons per acre of green chile and 3,500 to 4,000 pounds per acre of dried red chile. If a producer cannot grow these types of crops himself, there may be an option to lease the land for crop production.

Study area producers should investigate markets for alternative crops. The Black Range Resource Conservation and Development Corporation, the Cooperative Extension Service, and New Mexico State University could assist in market research.

Another objective of this report is to address the success of growing chile under sprinkler irrigation. Some farmers in New Mexico are apparently doing this. However, this is not a common practice in the State.

With good water quality, nothing should prevent a producer from growing chile under sprinkler irrigation, particularly with precautions.

In New Mexico, humidity is generally low enough not to be a problem. However, increased incidences of foliar diseases, such as Cercospora leaf spot and bacterial leaf spot, could be possible. These diseases can reduce yields and quality.

Using sprinkler irrigation for growing chile would require a higher level of management than furrow systems require.

An advantage of using sprinkler irrigation is the ability to apply fungicides and nutrients with the irrigation water. This practice saves labor and may be more economical. Monitoring the crop closely is a necessity. Chile and bell peppers are grown successfully

in California under sprinkler irrigation, but growers must use a high level of management.

Furrow irrigation is considered to be the best system for growing chile in New Mexico. Successful chile growers using a furrow system should continue using it.

EROSION ON IDLED CROPLAND

Another objective of the study was to assess erosion on abandoned cropland or idled cropland and to present methods, costs, and benefits in establishing perennial vegetation. Table 9 indicates the acreage of idled cropland in the study area in 1986. Currently, cropland has been idled in the area because of financial problems, participation in government programs (i.e., Conserving Use or Acreage Conservation Reserve), or lack of adequate return on investment for commodities grown.

Table 9. Idle Cropland Acreage By Basin for 1986 1/

Basin	Total Cropland 2/	Idle 3/	Program or Planted 4/
Luna County			
Mimbres	51,073	7,161	43,912
Nutt Hockett	10,899	211	10,688
Hidalgo County			
Animas	13,996	394	13,602
Lordsburg	8,781	3,552	5,229
Playas Valley	11,518	2,224	9,294
San Simon	2,907	661	2,246
Virden Valley	3,218	529	2,689
Totals			
Luna Co.	61,972	7,372	54,600
Hidalgo Co.	40,420	7,360	33,060
Study Total	102,392	14,732	87,660

1/ This was selected as the base year for the study.
2/ Total Cropland includes total acres with an agricultural water right.
3/ Idle acreage includes land not planted and not certified in a USDA program.
4/ Planted includes all planted and irrigated acres and all unplanted acres certified in a USDA program.

Idle land in the area is currently valued at $300 to $400 per acre. In 1986, 30,000 acres of the 40,000 acres of total cropland in Hidalgo County was not planted to a crop.

All of the cropland in the study area has a water right. Often, landowners do not plant permanent native cover because they risk loss of their water rights if they cannot demonstrate beneficial use of them.

Erosion on idle land was assessed to determine damages and problems. Water erosion ranged from 0 to 0.4 tons per acre per year, which is well below the allowable soil loss tolerance. Wind erosion, however, ranged from 0 to 9.5 tons per acre per year. Hondale soil erodes at 31.4 tons per acre per year and occurs on 82,334 acres in Hidalgo County. However, few of these acres are cropped. This soil is affected by sodium. The Wind Erosion Equation (WEQ) does not consider the surface crusting of Hondale soil. Actual

erosion rates for this soil will be less than that predicted by the WEQ. Overall, the idled cropland will erode at about twice the allowable tolerance.

When measuring damages from the increased wind erosion on the idle cropland, on-site and off-site effects must be considered. Previous studies on the economic effects of wind erosion show that off-site damages are more significant than on-site effects. Off-site effects from wind erosion include road and highway maintenance, household and business cleaning costs, health costs, and damage to personal property. Damages are caused by combinations of the clogging, abrading, and infiltrating properties of blowing sand and dust. Most of these damages are sustained over time and, as a result, are not very dramatic. An example of this type of damage would be the effects of blowing sand on vehicles. Their internal combustion engines and exterior surfaces are vulnerable to wind erosion damages. The SCS report, "Economics of On-Site Conservation Practices in Terms of Off-Site Benefits", used a model to calculate off-site damages caused by wind erosion. This model, or damage function, is dependent upon on-site erosion rates, composite population, and per capita income of that population. Based on this model, the off-site damages from wind erosion for Hidalgo and Luna Counties are estimated at $1.49 and $4.48 per acre, respectively. These figures are based on erosion rates reported in the 1982 National Resources Inventory. Assuming that erosion rates have not changed drastically since 1982, off-site damages from wind erosion on idle cropland can be estimated. In the study area, 44,418 acres of cropland are currently not producing a crop. Using the damage function, these acres account for $166,120 and $10,966 of damages in Luna and Hidalgo Counties, respectively.

On-site costs of wind erosion are derived mainly from costs of tillage operations and crop damage due to wind action. These damages would not be realized on idled acreage. However, this idle cropland would incur a reduction in soil productivity from wind erosion. The publication titled, "The On-Site Costs of Wind Erosion in New Mexico" estimates this damage to be 37 cents per acre per year. If this factor is applied to the study area acres, the on-site damages for the idle cropland would be approximately $16,300 per year.

Another damage created on idle cropland is the invasion of noxious weeds. Weed seeds are produced on the idle acres and blow onto the cultivated acres. No estimate of damages from this situation was made for this report. However, this damage is a serious concern of the farmers in the study area.

Erosion damages from the idle cropland are becoming less of a concern in the study area. More idle acres are being used to grow high value crops, such as chile, onions, and cabbage.

A practical method of establishing the idled cropland to native permanent cover was determined. It was initially assumed that agriculture in the study area was on the decline. It was also assumed that the cropland which was idle in 1986 would not be cropped in the future. However, the acreages planted in 1989 in Hidalgo and Luna Counties were 33,675 and 58,900, respectively. These figures represent a six percent increase in acres planted from 1986 to 1989. The increased acreage was planted to vegetable and specialty crops. This increase in planted acres may discourage the establishment of permanent cover on irrigated cropland.

Establishing permanent cover may not be practical for some landowners. It depends on the landuser's objectives, resources (land, labor, finances, equipment, and management ability) and the amount of risk he or she is willing to accept. The average cost of establishment for a field under irrigation with a dead litter crop is about $90.00 per acre

as opposed to $60.00 per acre without a cover crop. Both methods have no guarantee of establishment.

Best results for establishment can be obtained through good seedbed preparation, use of a dead litter cover crop, sprinkler irrigation, quality seed of adapted species, and cultipacking after seeding. Lehmann lovegrass, alkali sacaton, yellow bluestem, and fourwing saltbush are the grasses and forbs which are being planted in the area.

About 10,000 acres have been scheduled for establishment to permanent cover under the Conservation Reserve Program. Most of these acres have been planted without supplemental irrigation. The seeding survival rate has been about 25 percent. Therefore, three out of four seedings will be reseeded at least once. CRP seedings are cost-shared at a flat rate of $50.00 per acre. Each CRP contract provides about $40.00 per acre in annual rental payments for 10 years.

If a field is seeded to permanent vegetation using the Agriculture Conservation Program (ACP) or the Long-Term Agreement Program (LTA), the cost-share rate is 60 percent of the cost of establishment, excluding irrigation costs. These programs are available through the Agricultural Stabilization and Conservation Service (ASCS). The availability of such cost-share opportunities may also affect the practicality of establishing permanent vegetation on abandoned cropland.

<u>Summary</u>: Due to the costs involved in the establishment of permanent grasses, the limited return on investment, and other risks involved, it is unlikely that establishing permanent cover will be practical for many producers in the study area.

Few crops, if any, provide sufficient net returns to solve financial problems. Acreage in CU and ACR will probably remain at about the same level from year to year depending on the availability of government programs. The remainder of the land that is being idled may benefit from being planted to high value truck crops, such as chile, onions, and cabbage.

DESCRIPTION OF THE STUDY AREA

The study area includes Hidalgo and Luna Counties in the southwestern corner of New Mexico. Hidalgo County consists of 2,204,900 acres. Luna County consists of 1,897,700 acres. This study focused on cropland within Hidalgo and Luna Counties. These counties contain 40,420 and 73,950 acres of cropland, respectively.

The mean annual precipitation is less than 10 inches and is not sufficient to produce dryland crops. The growing season ranges from 187 to 214 frost free days. The average annual temperature is 61 degrees Fahrenheit.

The topography of Hidalgo County varies from alkali flats and playas through semi-desert plains to rough and broken mountain ranges. The elevation ranges from 3,700 to 8,532 feet. There are six mountain ranges and several hilly regions which bound five groundwater basins.

The topography of Luna County consists of semi-desert plains interrupted by four mountain ranges. The elevation ranges from 4,000 to 8,404 feet. The principal drainage is formed by the Mimbres River. Flows in this river are intermittent and seldom reach the vicinity of Deming. Elsewhere, surface drainage is ill-defined, and intermittent arroyos terminate in a series of playas, or dry lakes.

Cropland in Hidalgo County is divided among the five groundwater basins. Cropland in Luna County is located in two groundwater basins. Table 10 shows the cropland acreages in each county.

Table 10. Land Use in Hidalgo and Luna Counties

	Hidalgo	Luna
Federal Land	828,880	746,547
Non-Federal Land	1,376,020	1,151,153
Irrigated Cropland	40,420	73,950
Dry Cropland	0	0
Rangeland	1,275,514	1,037,443
Woodland	20,000	988
Urban Land	2,700	4,500
Roads and Highways	7,386	9,353
Other Land	30,000	24,919

The population of Hidalgo and Luna Counties is 6,100 and 18,100, respectively. Deming is the largest municipality with 10,609 people. Lordsburg is the next largest with 3,202. All other communities have a population of less than 2,500.

Soils information for the study area is available from the Soil Conservation Service. Published soil surveys are available for both counties. The geology of the area shows that during the Quaternary Period, lakes occupied the area. Thick lacustrine deposits were laid down in the lake bottoms. These deposits were saturated with water. As the climate changed, the lakes, or playas, dried up. The saturated deposits form the

groundwater aquifers which, today, yield water for irrigation, residences, and municipalities.

In Hidalgo County, agriculture accounts for 80 percent of all water withdrawn. In Luna County, agriculture accounts for 96 percent. From 1974 to 1984, planted acreage in the two counties decreased by 41 percent. Increasing depth to groundwater and increasing energy costs caused the decline. The increasing depth to groundwater was caused by overdraft of the aquifers. Since 1986, the depth to groundwater has stabilized due to the 41 percent decrease in planted acreage. Since 1987, the number of planted acres has increased. These added acres are planted to shallow rooted crops which use less water per season than the traditional cotton, alfalfa, and sorghum.

Groundwater in the closed basins of southwestern New Mexico is produced primarily from an "unconfined" aquifer composed mostly of sediment from the erosion of volcanic rocks. This material has been transported by gravity, wind, and water into basins which had no drainage. These deposits are called "bolson deposits", and consist of fragments of rock which range in grain size from microscopic clays to very durable gravels and boulders. These materials are usually mixed in an infinite variety of ways, but they can also be deposited in very well sorted deposits. The ratio of fine to coarse particles basically determines the potential porosity and permeability of these deposits. This potential for wide variations in permeability does occasionally produce an "artesian" aquifer within a bolson deposit.

Generally, the water found in bolson deposits is deposited as the sediment accumulates. As the thickness of the deposit increases, dynamic forces within the aquifer tend to influence the quality and quantity of water which a given aquifer will yield.

Recharge of bolson deposits in arid areas is usually quite slow. Recharge is dependent on precipitation and vertical permeability of bolson deposits which is usually very poor.

Higher recharge rates can occur where highly permeable streams are incised into a previous section of the bolson deposit; permeable rock outcrops are adjacent to the bolson deposit; and permeable beds of the bolson deposit are exposed due to erosion or faulting.

Artificial recharge of bolson deposit aquifers has been attempted in many parts of the world, but it is not economical.

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